RHIC & AGS Users' Meeting 2023

sPHENIX Calorimeters

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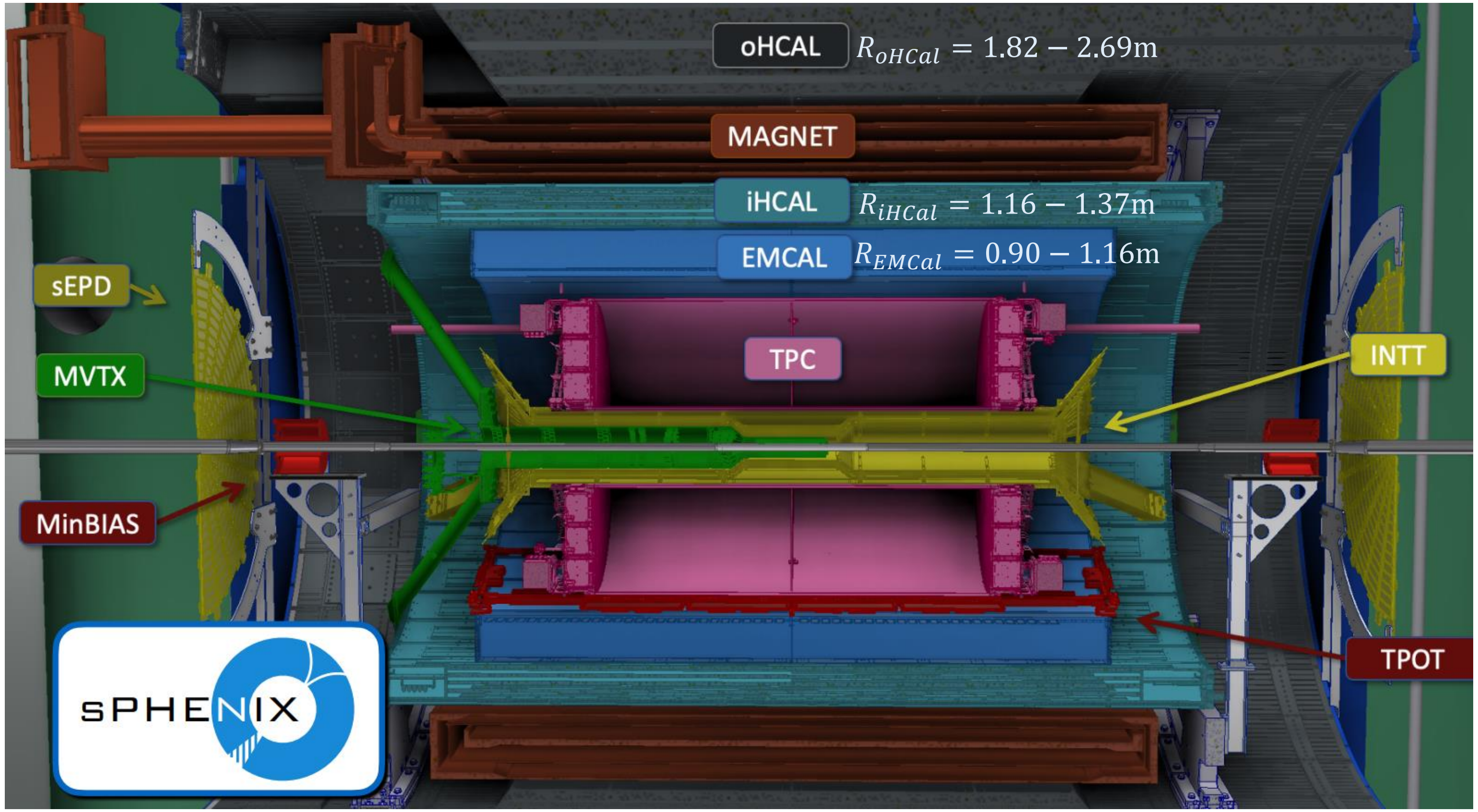
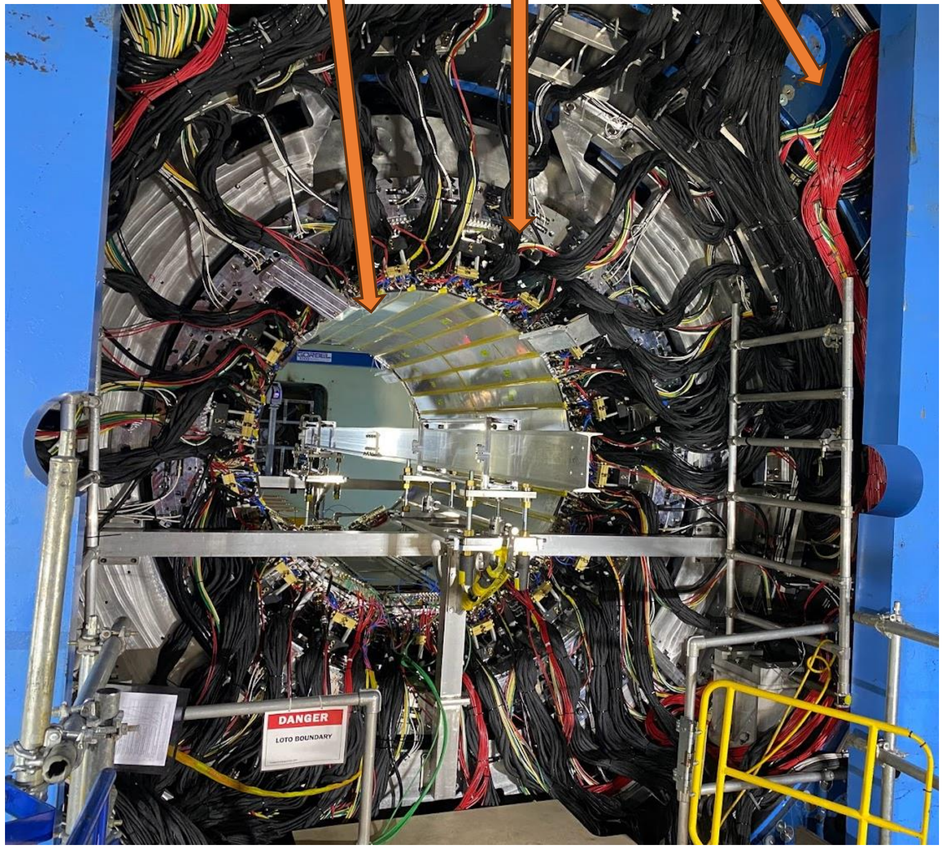
Aug 2nd, 2023

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

sPHENIX Calorimeters

EMCal iHCal oHCal

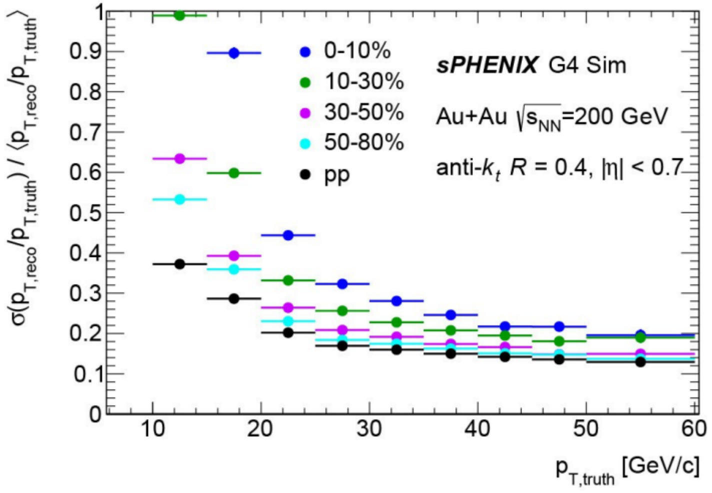




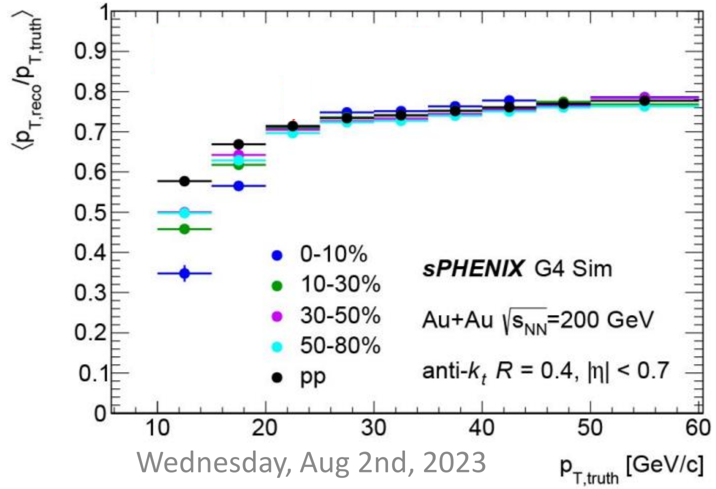
A prototype of the sPHENIX calorimeter system was tested at the Fermilab Test Beam Facility in 2016. (arXiv:1704.01461)

sPHENIX Calorimeters Jet Program

Jet Energy Resolution

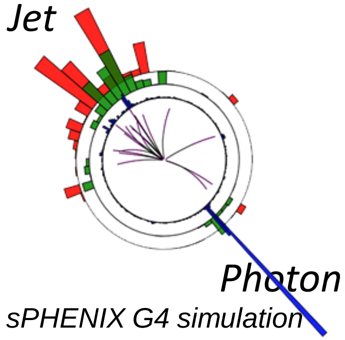


Jet Energy Scale



JER and JES:

- Jets from clusters of calorimeter towers.
- Event-by-event underlying event subtraction.
- EM-scale jets, no flow subtraction.



sPHENIX G4 simulation
Pythia8, 35 GeV γ+jet event

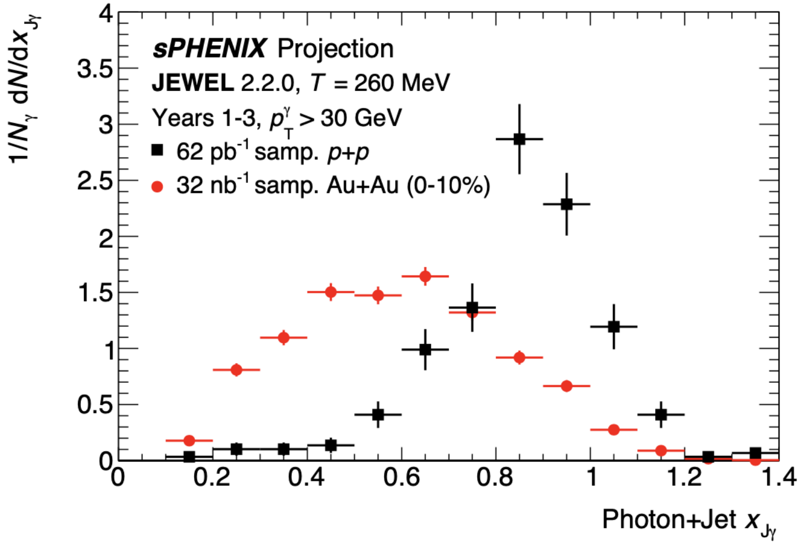
Jet-to-photon momentum balance

$$x_{J\gamma} = p_T^{jet}/p_T^{\gamma}$$

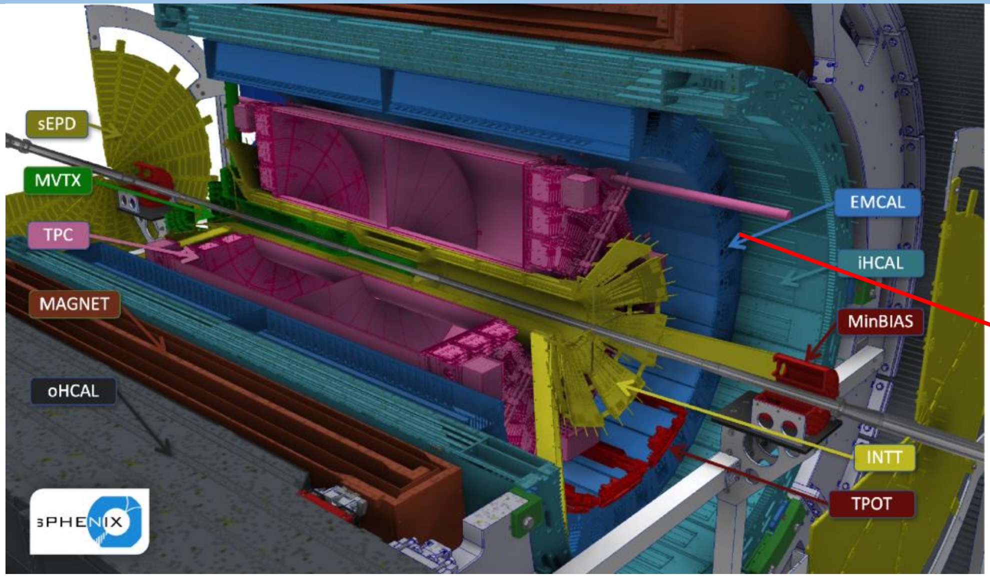
$x_{J\gamma}$ distribution for Au+Au shift towards lower value due to jet quenching.

A direct measure of the jet energy loss.

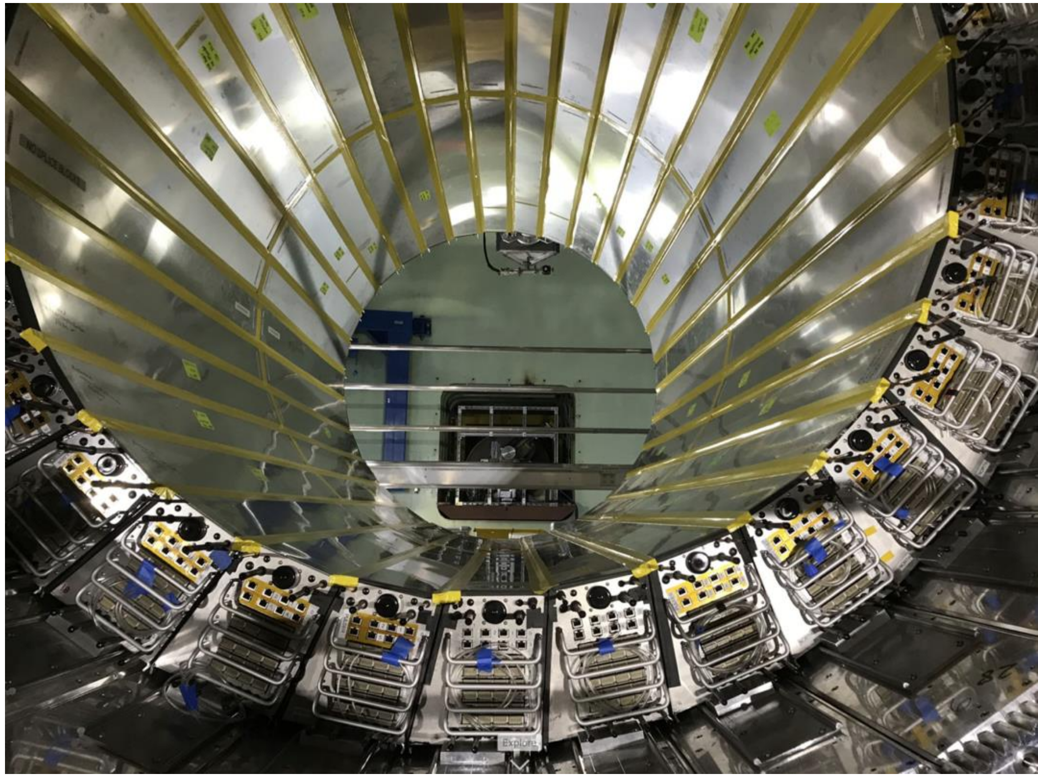
Jet-to-photon Momentum Balance



Electromagnetic Calorimeter



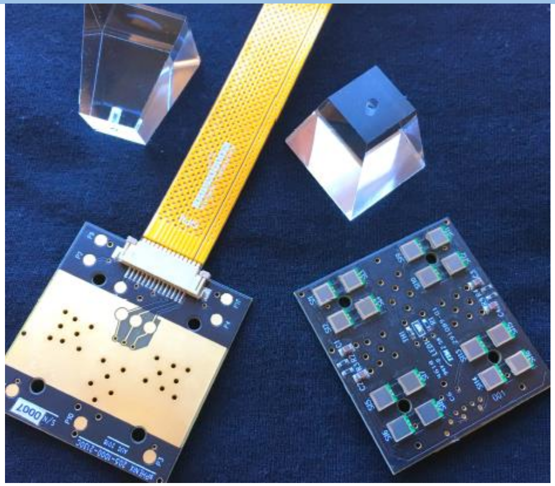
- Tungsten–scintillating fiber sampling calorimeter.
- Locate outside TPC & TPOT.
- Cover full azimuthal angle $2\,\pi$ and $|\eta|$ < 1.1.
- 64 sectors total: 32 azimuthal x 2 longitudinal.
- Interaction length: 0.83 λ_{int}. Radiation length: 20.1 X_0
- Moliere radius R_M ~ 2.3 cm in EMCal.
- Energy resolution: $\sigma_E/E\, = 5\% \oplus 16\%/\sqrt{E}$

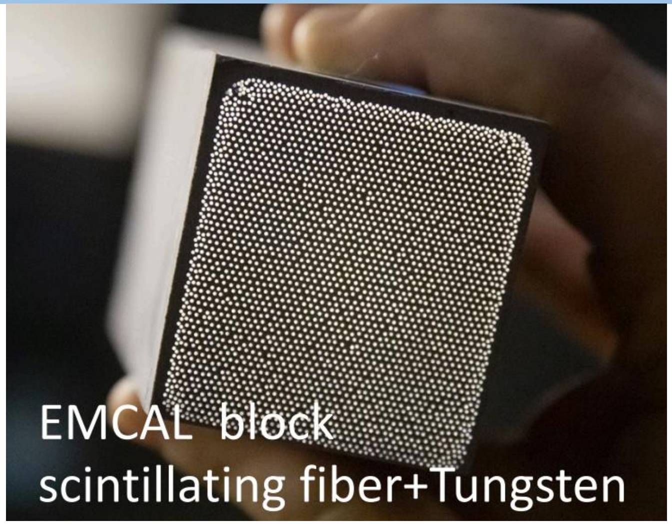


Installed Nov. 2022

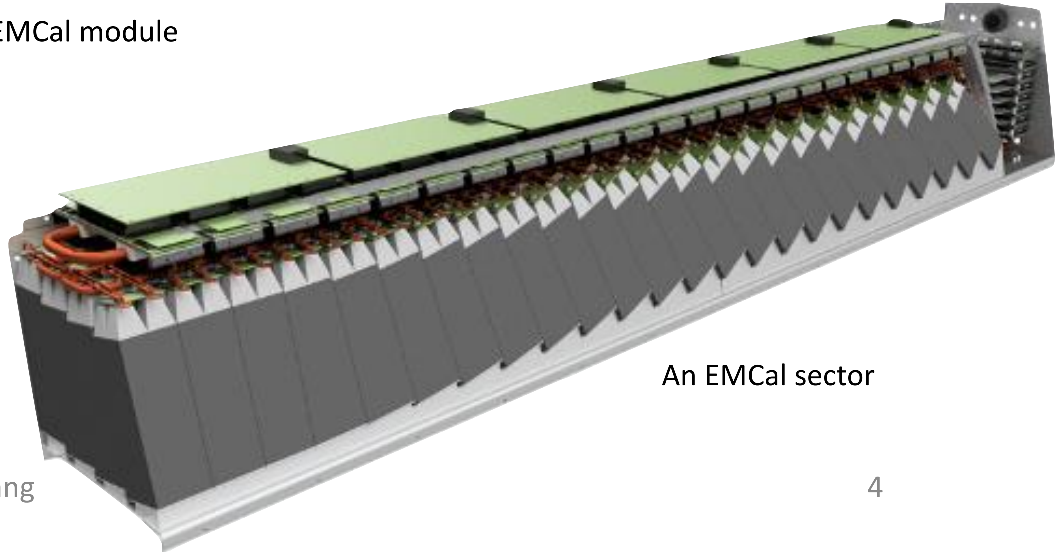
Electromagnetic Calorimeter

- Each sector will subtend 11.2° in ϕ, 1.1 units in η. Two sectors cover the η acceptance from -1.1 to 1.1.
- A sector contains 96 modules. Each module is an absorber block that is divided into 2x2 towers.
- Each tower has a light guide at the inner surface and is read out with 4 silicon photomultipliers (SiPMs). One pre-amp board sums the signal from 4 SiPMs together to read out.
- 96 modules in a sector: 4 azimuthal x 24 longitudinal, that 8 x 48 = 384 towers in a sector. Towers tilts in η to point to center, and slightly in ϕ.
- There are totally 256 azimuthal x 96 longitudinal = 24576 towers, with each tower covers $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$



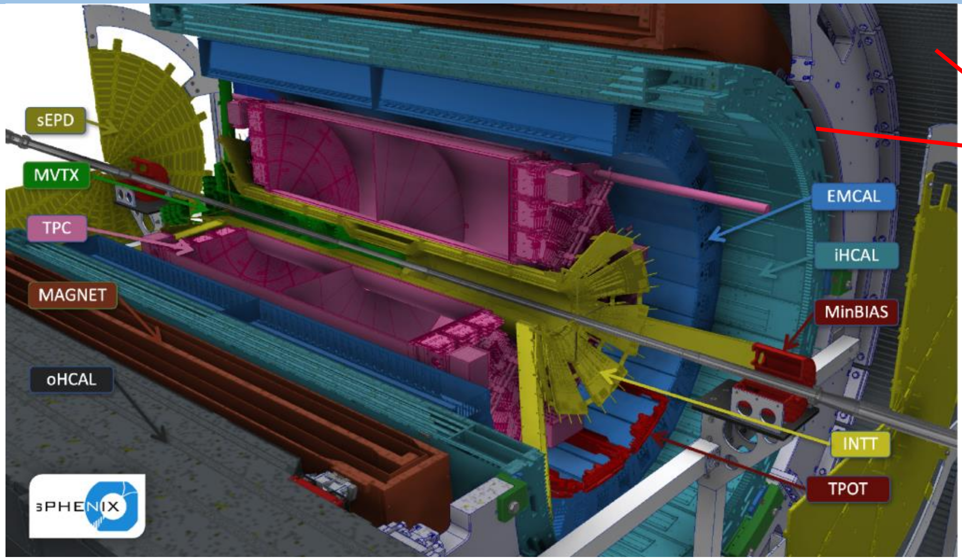


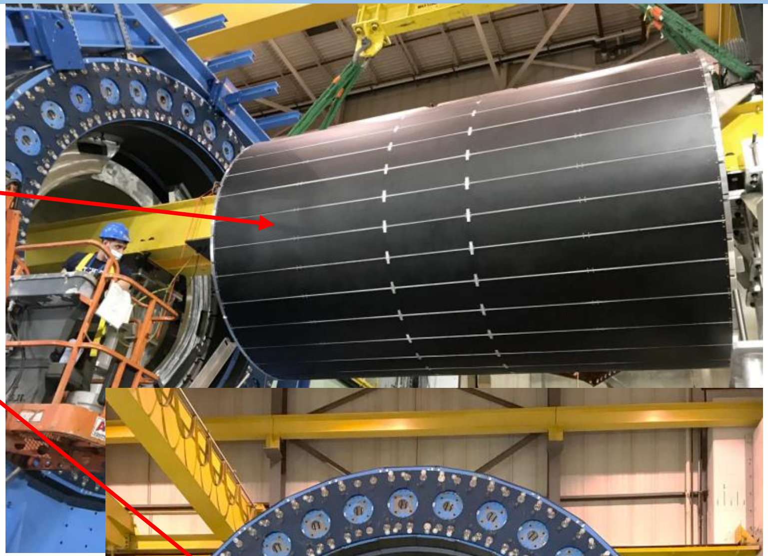
An EMCal module



An EMCal sector

Hadronic Calorimeters





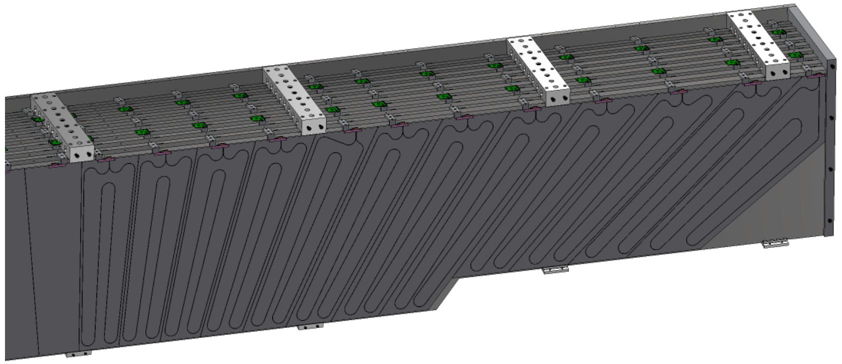
iHCal

oHCal

- First mid-rapidity hadronic calorimeter at RHIC.
- Al (inner) and steel (outer) absorber plates, scintillating tiles with embedded WLS fibers.
- Locate outside the EMCal, with the magnet intervening in between.
- Covers $|\eta| < 1.1$ and full azimuthal angle 2π with 32 sectors (for both i&oHCal).
- Overall HCal energy resolution: $\sigma_E/E \sim 14\% \oplus 81\%/\sqrt{E}$ for hadrons,
  $\sigma_E/E \sim 11\% \oplus 31\%/\sqrt{E}$ for electrons.
- Total 5 λ_{int} for both calorimeters combined.

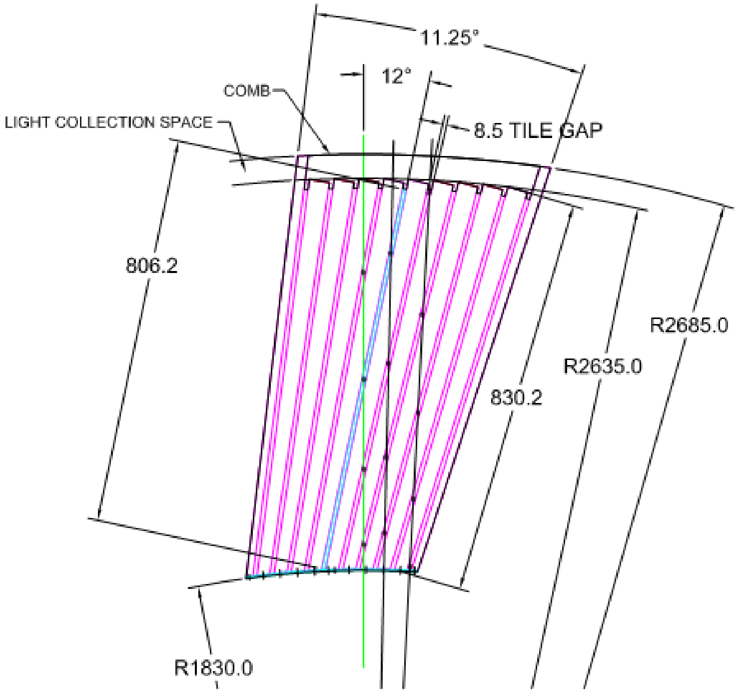
Hadronic Calorimeters

- One oHCal sector has 10 scintillator slots. One iHCal sector has 8 scintillator slots.
- Each slot is filled with 24 tiles along z. Tiles have different sizes and shapes to be projective in η.
- Tower is the collection of tiles. 5 tiles in oHCal, and 4 tiles in iHCal. One sector has 48 towers that separated into two lines.
- Total 1536 towers. Each tower covers $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$. Each HCal tower corresponds to 16 EMCal towers.
- The tiles are tilted in ϕ. oHCal tilts 12° relative to radius, iHCal tilts 32° in opposite direction. Particles from center will pass at least 4 tiles.
- A SiPM is installed on each tile. All 5 or 4 tiles' SiPMs in the same one tower are read out together.



Half of oHCal sector. oHCal scintillating tiles tilted in η from center of barrel

IHCal scintillating production



OHCal scintillating tiles tilted in φ from radius

Monitoring & Calibration

Calorimeter monitoring methods:

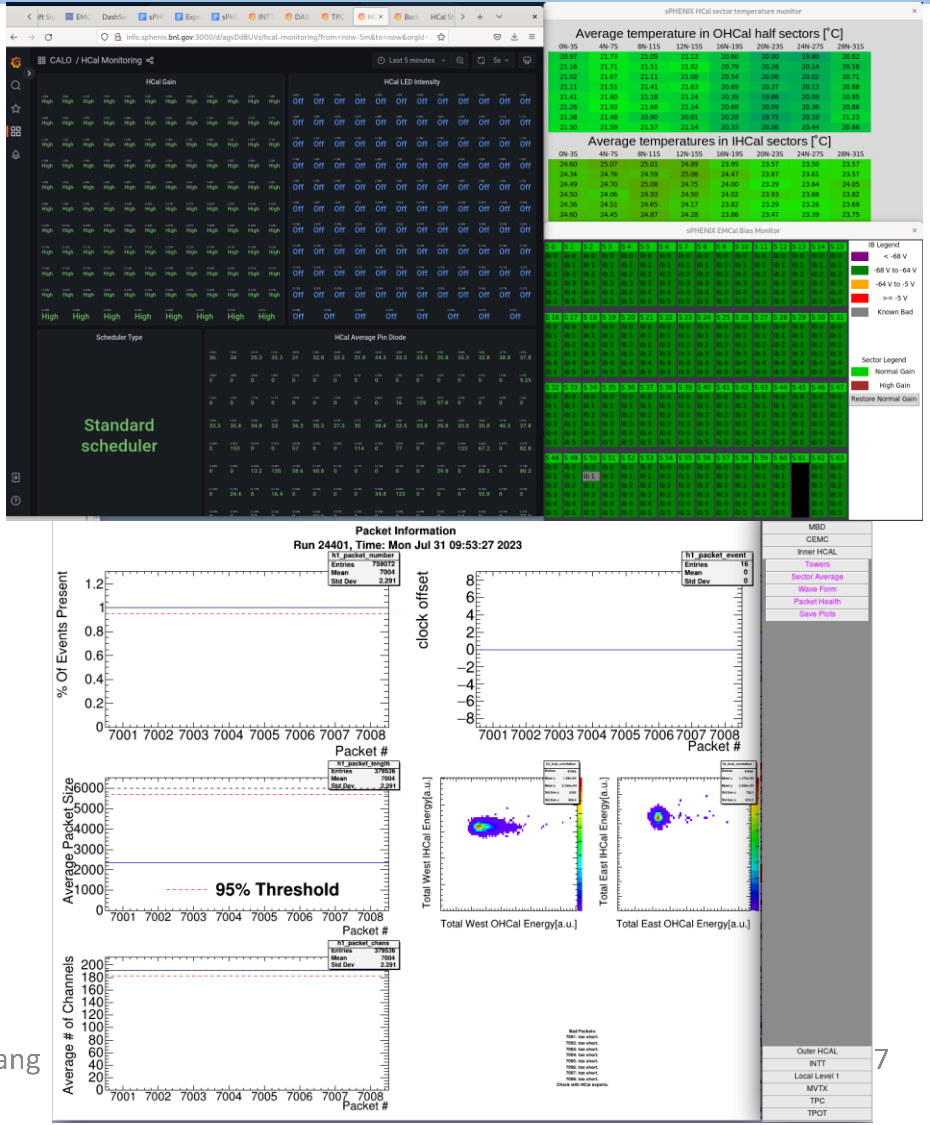
- Detector status information is monitored through slow control cables, such as bias voltage and temperature.
- Online monitoring is set up for shifter, basing on channels' running mean packet status, waveform and so on.
- Test pulse runs and LED runs are taking regularly to monitoring the status of HCal.

Calorimeter relative calibration:

- MIP calibration with cosmic muon. (Pre-installation preliminary calibration done separately for EMCal and HCal)
- Ongoing tower slope method for EMCal.

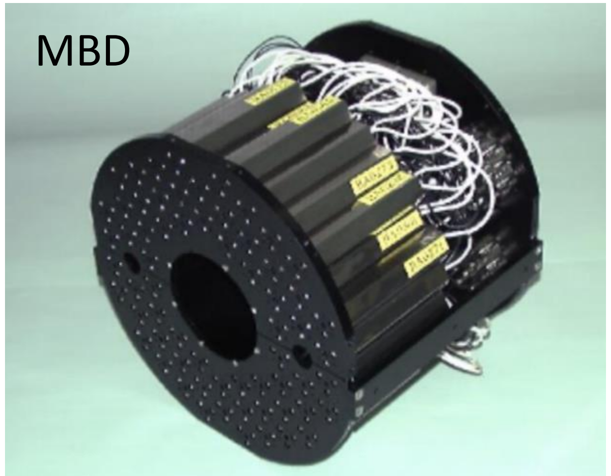
Ongoing absolute calibration:

- π^0 tower-by-tower calibration and get overall energy scale for EMCal.
- Correlation between cosmic muon MIP and Geant4 simulation to get the electromagnetic energy scale for HCal.

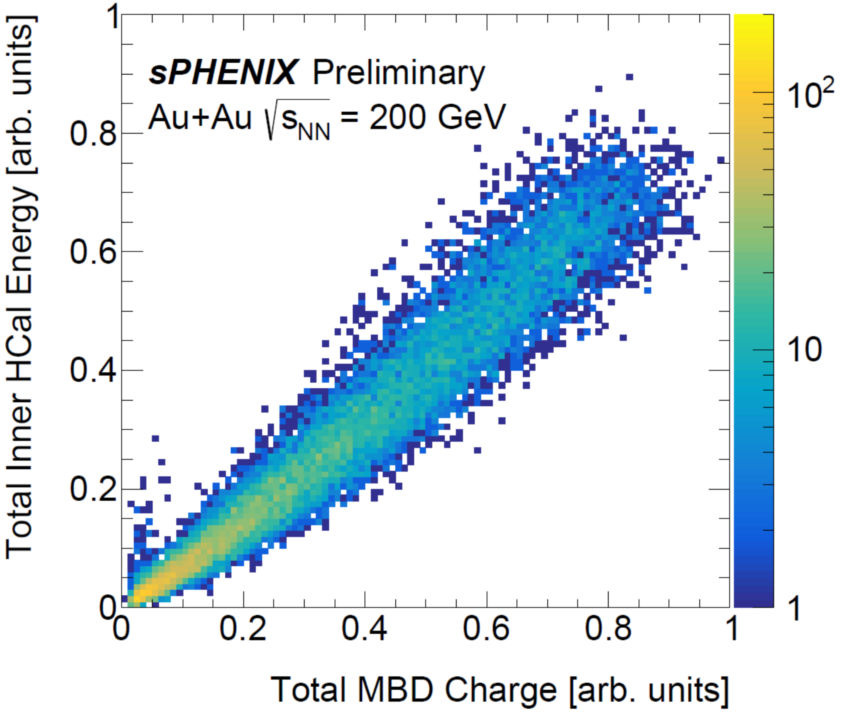


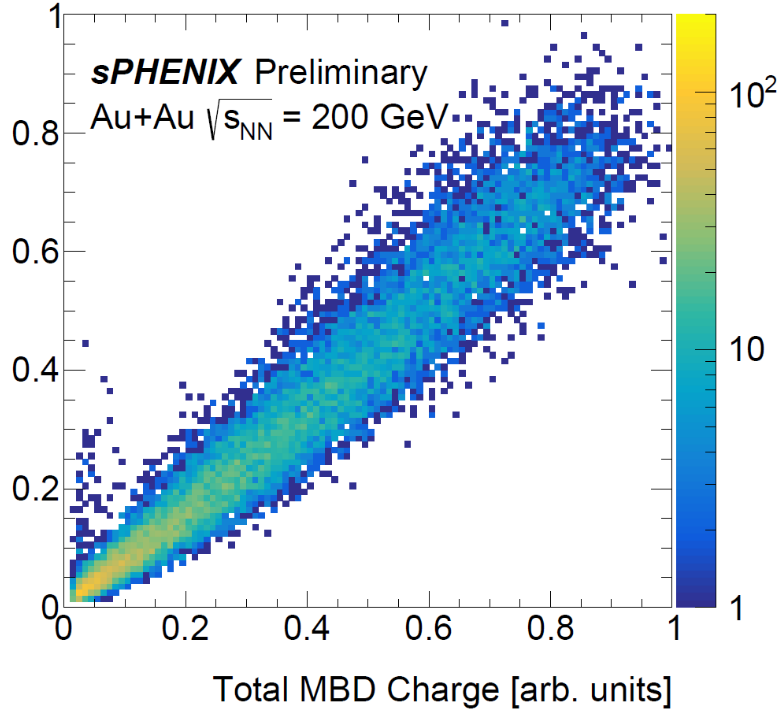
Calorimeters Commissioning

The correlation between the total energy in the o/iHCal and total charge in the minimum bias detector (MBD) in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV.

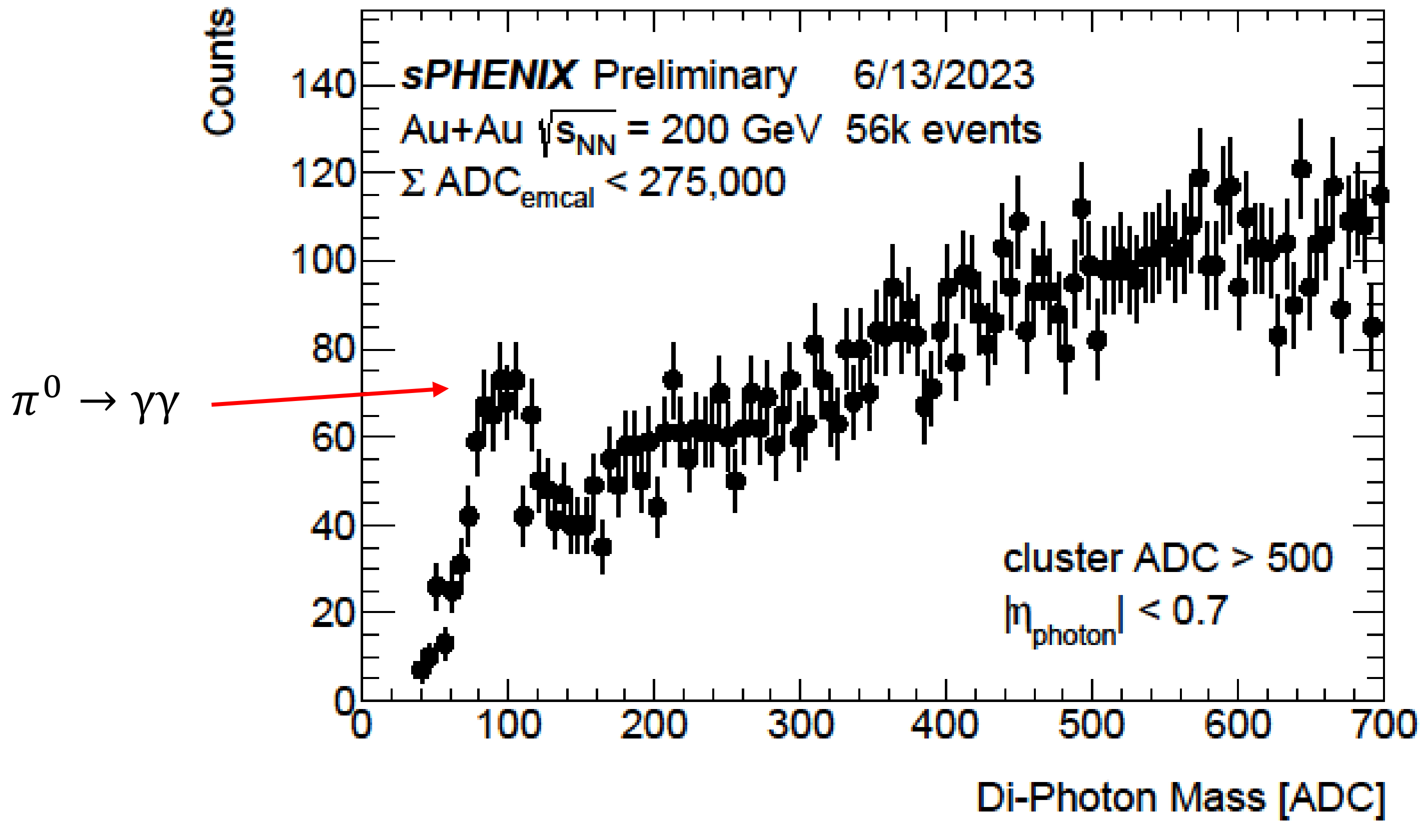


- 64 channels each side of 3cm thick quartz radiator on mesh dynode PMT.
- Covers 3.51 < $|\eta|$ < 4.61.
- Timing resolution: 120 ps.



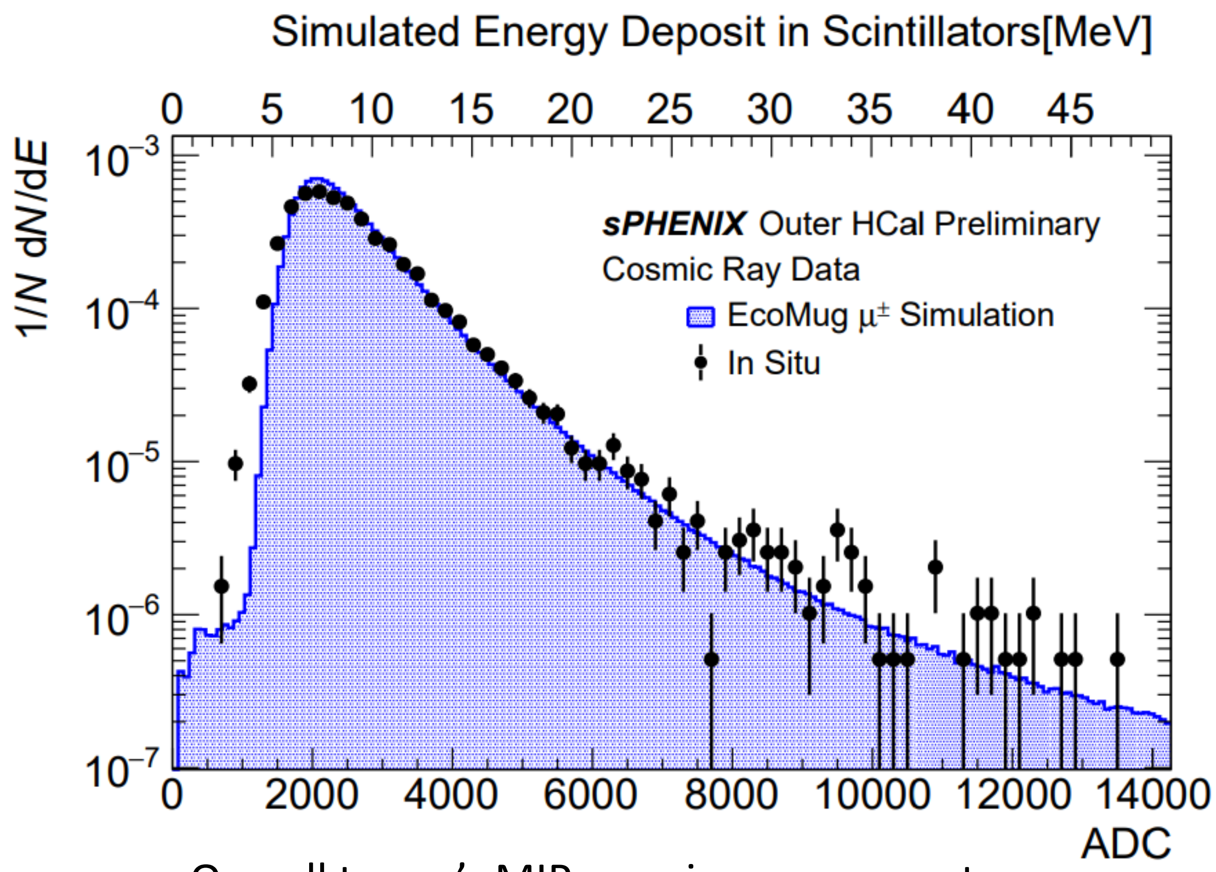


First EMCal Physics Signal

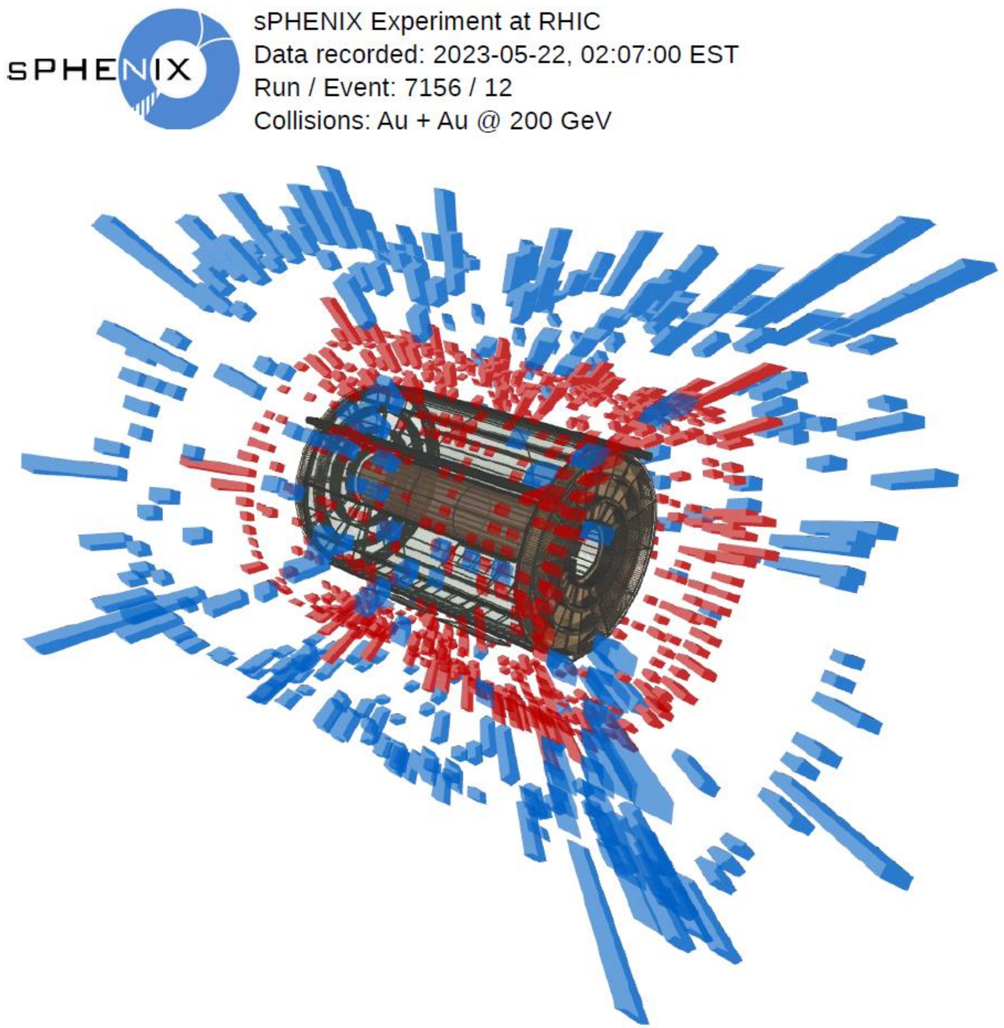


The di-photon mass distribution in units of ADC. π^0 peak around 90-100 ADC.

Early HCal Commissioning Result



Overall tower's MIP cosmic energy spectrum
(with direction perpendicular to radius)



Summary

Summary:

- sPHENIX calorimeters are both functional and have preliminary calibration data.
- More ongoing calibrations making good progress.
- The calorimeters commissioning verify that calorimeters are ready for physics data taking.
- First-year jet analysis basing on calorimeters are underway.

Related talks and poster:

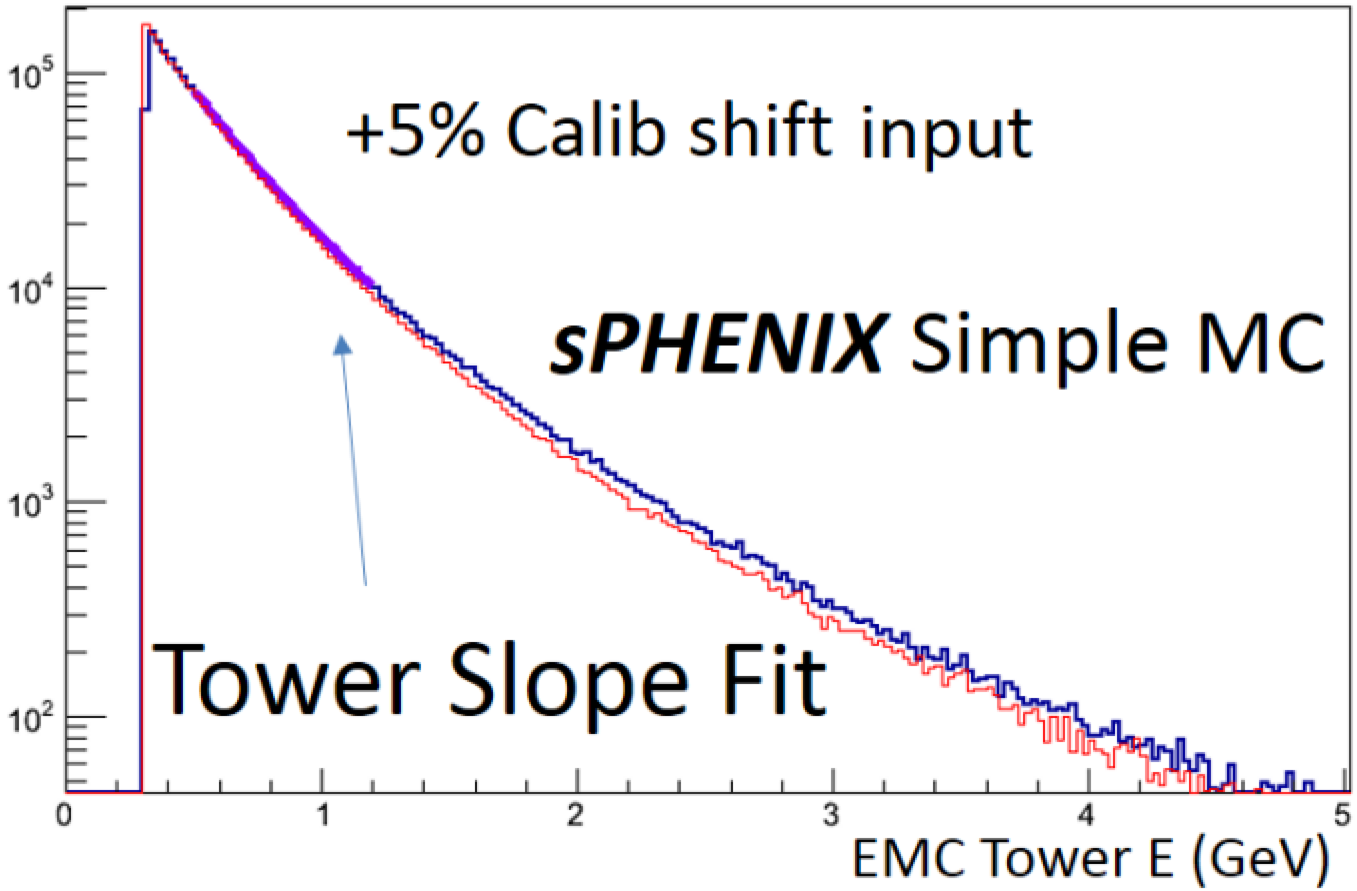
- *sPHENIX Overview* - Ejiro Umaka
- *Progress Toward Jet Physics Measurements in sPHENIX* - Anthony Hodges
- *Commissioning Status of the sPHENIX Electromagnetic Calorimeter (POSTER)* - Abraham Holtermann, Marzia Rosati

Thank you!

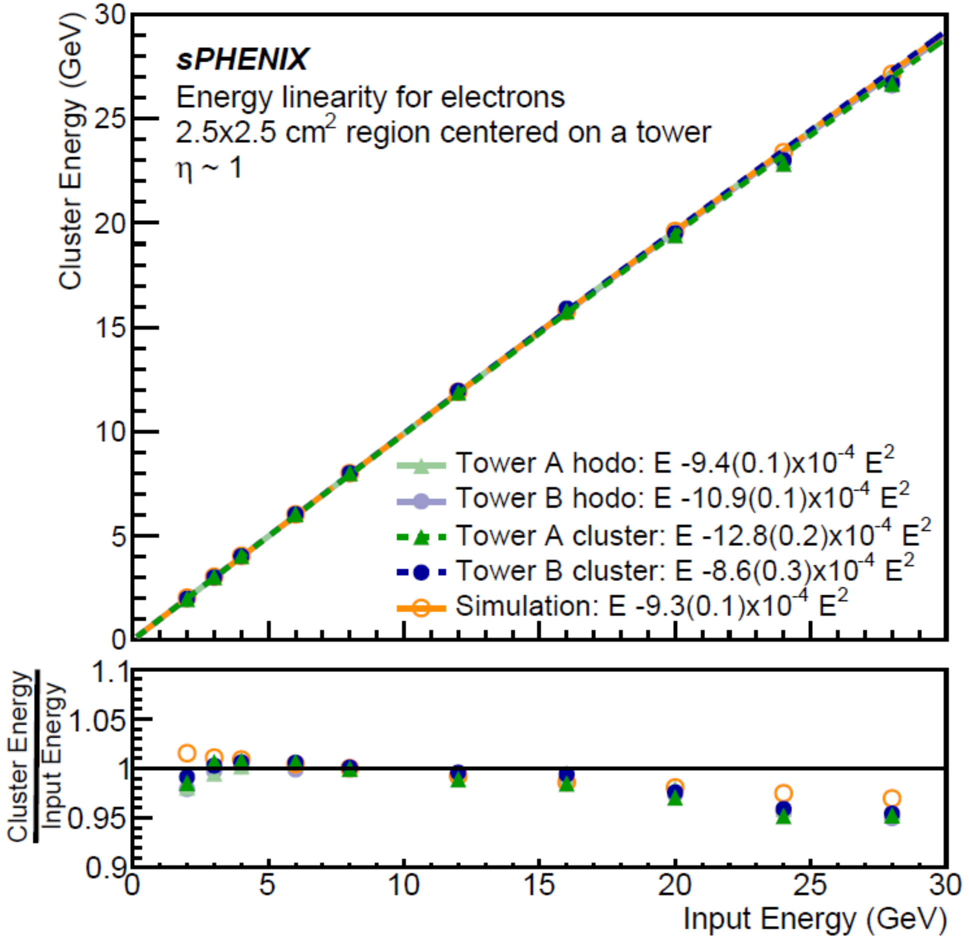
Backup

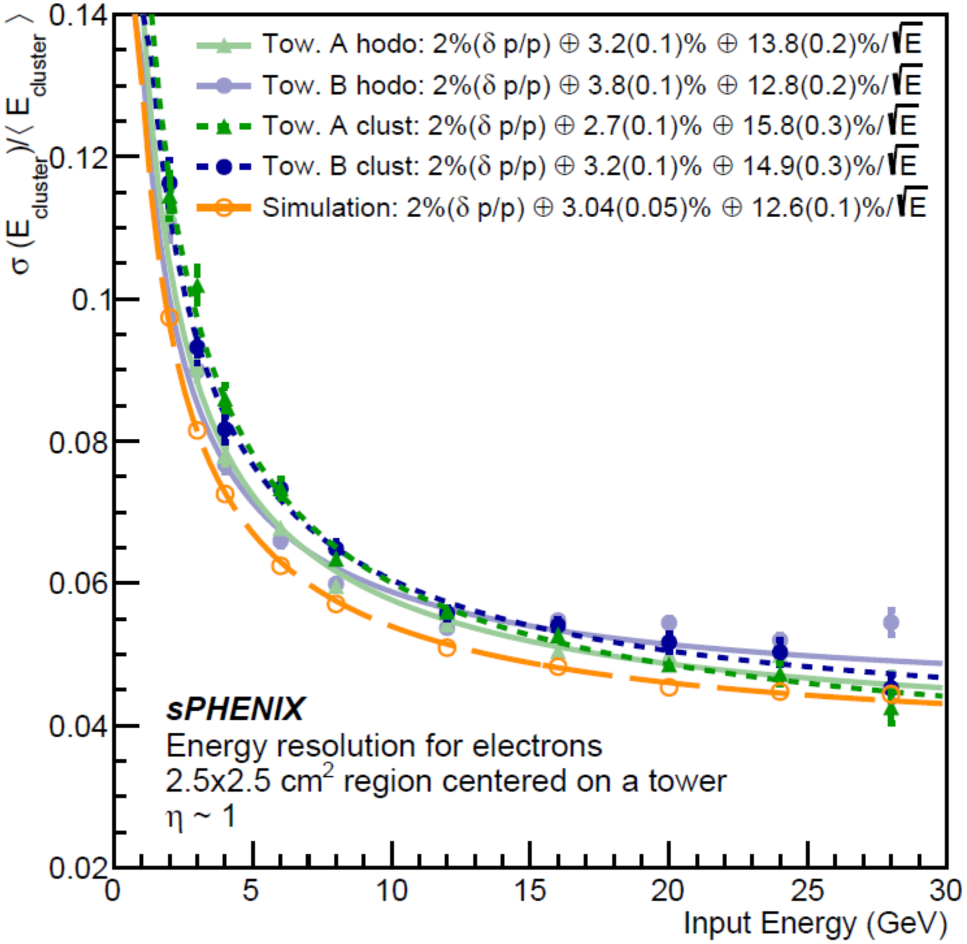
EMCal Tower Slope Method

EMCal tower's energy distribution



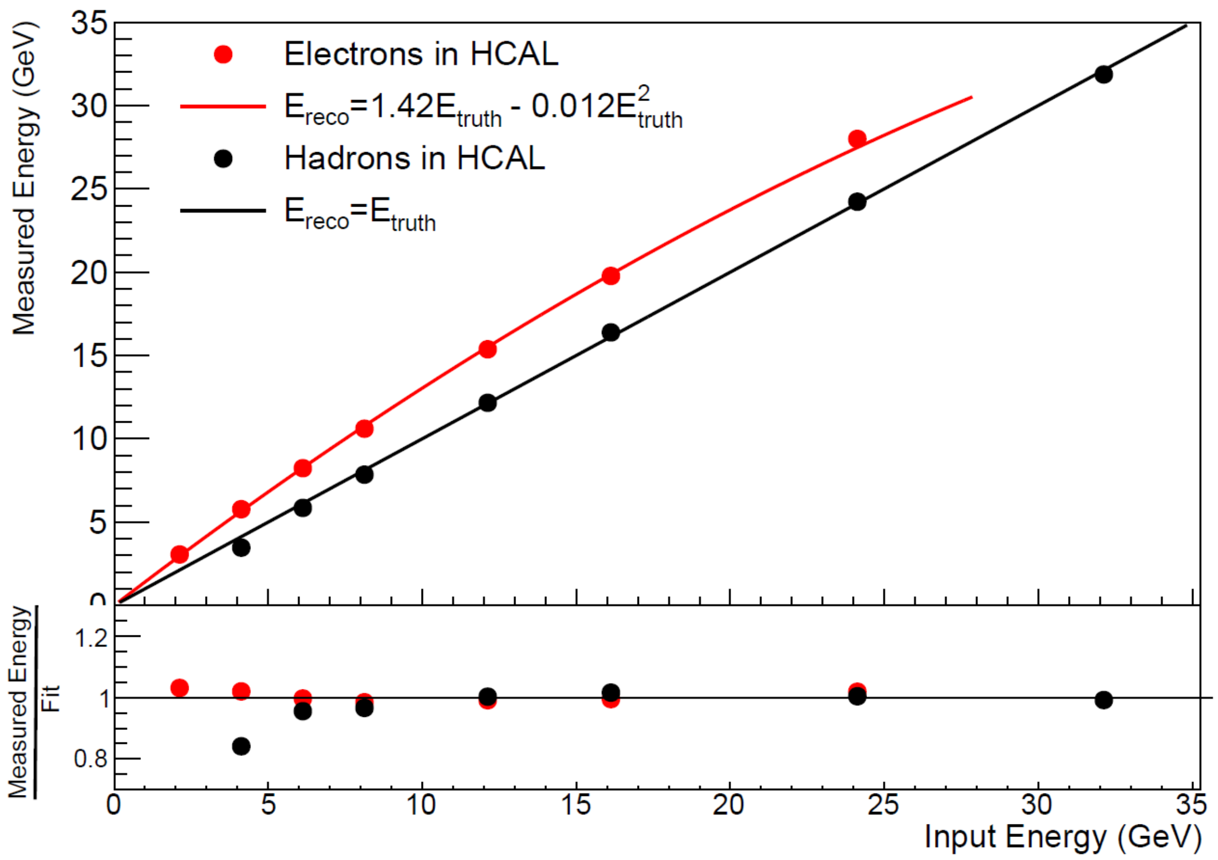
EMCal Resolution

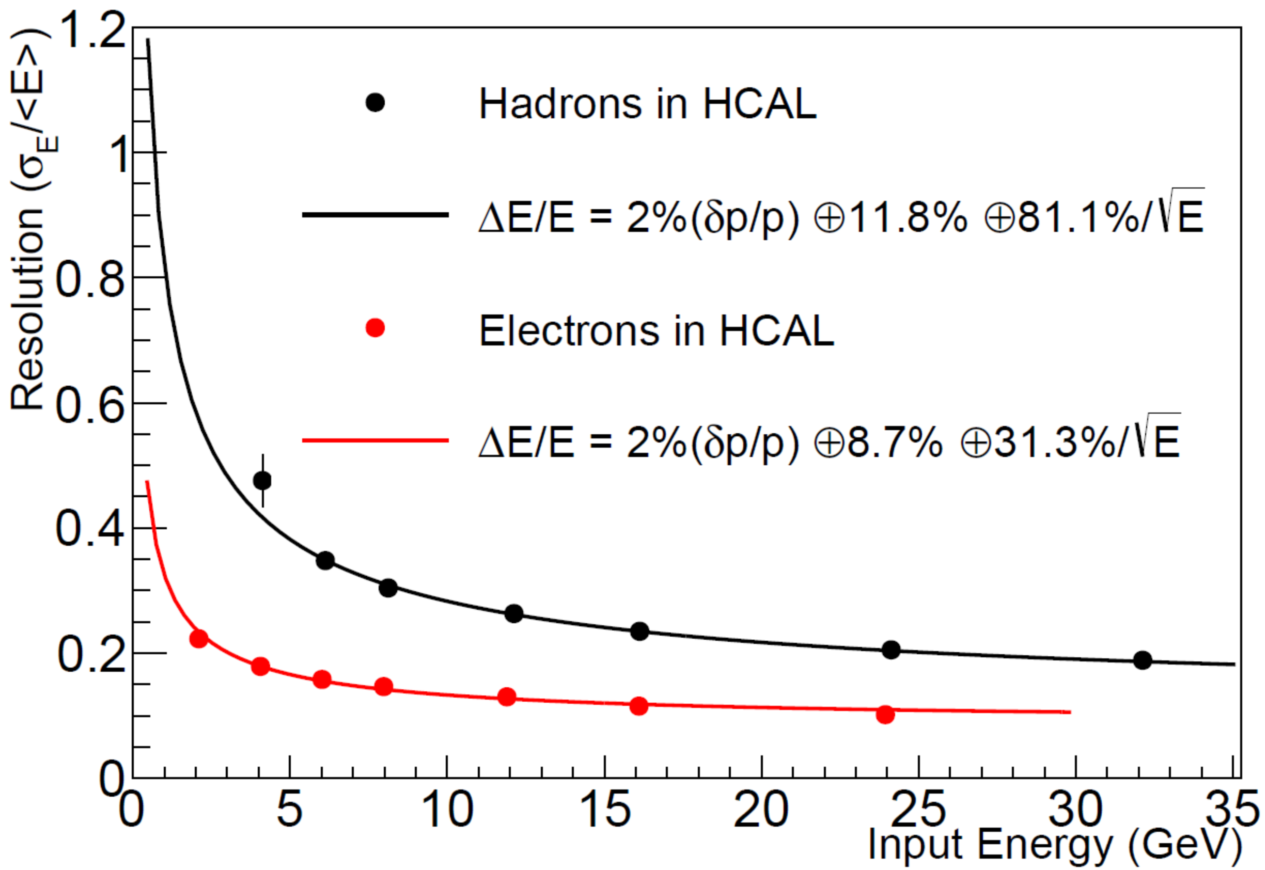




Design and Beam Test Results for the 2D Projective sPHENIX Electromagnetic Calorimeter Prototype (arXiv:2003.13685)

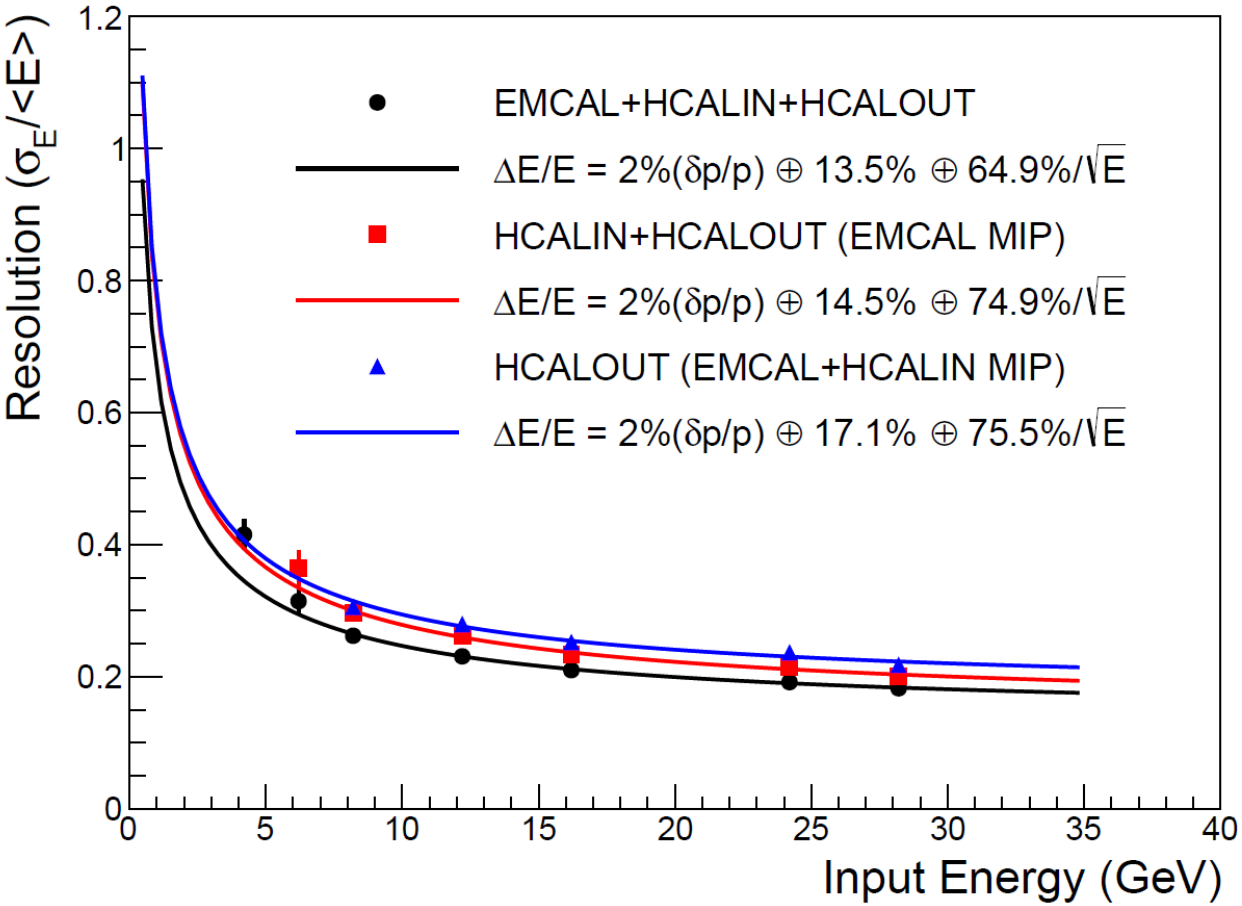
HCal Resolution





Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes (arXiv:1704.01461)

Hadron Resolution



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